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HOST RANGE OF POTATO LEAFROLL VIRUS[1]

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It has been assumed rather generally that the leafroll disease was brought along with the introduction to Europe of the potato, inasmuch as some descriptions of diseases of potatoes in the early literature indicate most strongly that leafroll was one of the diseases involved. The ready transmision of leafroll virus to all species and varieties of potato thus far tested could be interpreted as an indication that the potato is not a natural host of the virus and was not exposed to leafroll virus until introduced into the Old World. One has to bear in mind, however, that a few varieties exhibit just enough resistance to suggest an inherent condition. Also, species of "wild potatoes" that are not obviously useful have not been tested sufficiently. The discovery that some of these species possess resistance or immunity to leafroll virus would go far to settle the questions raised in the preceding remarks. In addition, the discovery of such a plant could represent the foundation for a program of development of the potato which would lead to the permanent protection of this plant from an insidious and destructive disease, provided that such resistance represents a heritable character. Obviously it would be simpler to locate this character in a variety that is already acceptable from a commercial standpoint, but in view of the several known cases of interspecific hybridization in the genus *Solanum*, all varieties and all species should be tested.

Although there is no good evidence that in potato-growing areas leafroll virus overwinters in anything other than infected tubers of commercial potato varieties, it is possible that other suscepts may function as reservoirs in some areas or in some seasons. A better knowledge of the host range of the virus, among both solanaceous and non-solanaceous species, could aid in the detection of overwintering suscepts, if such exist. Additional suscept range studies could also lead to the discovery of indicator plants or source plants superior to those known to date.

Because of the obvious need for further host range studies and the discovery of suitable indicator plants for leafroll virus, Dykstra, *et al* (3, 5, 6), the susceptibility of many solanaceous and non-solanaceous species was determined. The list of species tested includes several *Solanum* species or "wild potatoes," some weeds found in or near potato fields, and some common ornamentals. Inoculations were by means of aphids, and with

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a few exceptions, attempts were made to recover the virus from all inoculated plants by means of aphids. In these recovery tests, the indicator plant most generally used was *Physalis floridana* Rydb., although *P. angulata* L. and *Datura stramonium* L. were used in some cases.

Review of Literature

Prior to the initiation of this work, the known suscepts of potato leafroll virus were restricted to the family *Solanaceae* with a few possible exceptions. Salaman and Wortley (10) reported that leafroll virus was successfully transmitted to Campanula, to Matthiola and to turnip by grafting and to Brussels sprouts by means of aphids. However, Helson and Norris (4) were unsuccessful in transmitting the virus, either by aphids or by grafts, to 11 crucifer species, including turnip and Brussels sprouts.

Most reported attempts to infect solanaceous species have been successful. All varieties of *Solanum tuberosum* L. are susceptible. Quanjer (8) reported that plants of *Nicotiana tabacum* L., *Atropa belladonna* L., *Datura stramonium* L., *Hyoscyamus niger* L., *Solanum nigrum* L. and *S. dulcamara* L. can be infected by means of aphids or grafts. Dykstra (3) stated that the virus was transmitted by means of aphids to plants of *Datura stramonium, D. tatula, Lycopersicum esculentum, Solanum dulcamara,* and *S. villosum*. *Physalis angulata* was reported as susceptible by Hovey and Bonde (5). Kirkpatrick (6) found *P. floridana* Rydb. to be susceptible.

Several collections of various Solanum species have been tested for susceptibility in Germany. In tests by Stelzner, first reported by Ross and Baerecke (9) and later more completely by Stelzner (11), the following species appeared to be susceptible to leafroll virus when inoculated by graft: *Solanum acaule* Bitt., *S. antipoviczii* Buk., *S. bukasovii* Juz., *S. chacoense* Bitt., *S. caldasii* Dun., *S. cordobense* Buk., *S. demissum Lindl., S. fendleri* A. Grey, *S. garciae* Buk. & Juz., and *S. verrucosum* Schlechtd. Ross & Baerecke (9) inoculated the following by means of aphids: *S. ajuscoense* Buk., *S. andigenum* Juz. & Buk., *S. antipoviczii, S. catarthrum* Juz., *S. chacoense, S. cordobense, S. demissum, S. leptostigma* Juz., *S. macolae* Buk., *S. polyadenium* Greenm. *S. verrucosum,* and *S. wittmackii* Bitt. Some plants of each species developed symptoms. A few individuals of *S. andigenum, S. catarthrum,* and *S. chacoense* remained symptomless but none of these plants was tested for presence of the virus. All hybrids with *S. tuberosum* except one with *S. chacoense* were susceptible to leafroll.

Materials and Methods

Mature wingless forms of the peach aphid, *Myzus persicae* (Sulzer), were used in attempts to transmit the virus to and from the test species. The aphids subsequently referred to as viruliferous were reared on infected plants of *Datura stramonium* L. Non-viruliferous aphids were reared on cabbage *(Brassica oleracea* var. *capitata* L.*)* or turnip *(B. rapa* L.*)*. The two groups were maintained in separate insectary chambers in the greenhouse. Aphids were transferred from plant to plant by means of a camel-hair brush. Each plant infested with aphids, either test plant

or indicator plant, was caged in a 2 x 6 in. Pyrolin cylinder covered on top with fine cheesecloth.

Usually, 5 to 6 plants of each species were tested for susceptibility. Fewer plants were used in only a few cases. All but a few of the plants were grown from seed. Seedlings were transplanted, one plant per pot, to autoclaved soil at about the time of unfolding of the first true leaf. Ten or more days later, depending upon the rate of growth, each seedling was colonized with viruliferous aphids, 5 to 10 in the case of solanaceous plants and 10 to 15 in the case of others. The cages were removed 5 to 6 days later and the plants fumigated with nicotine sulfate. The plants were kept on a greenhouse bench and observed from time to time over a 3- to 6-week period. They were again fumigated and colonized with non-viruliferous aphids. After the aphids had fed for 5 to 7 days, 1 to 10 from each plant were transferred to at least 2 indicator plants. At least 5 aphids were used when the test plants were non-solanaceous, and 1 to 5 when they were solanaceous. The aphids were allowed to feed for 5 to 6 days on the indicator plants and then were killed by fumigation. The plants were transferred to a bench in the greenhouse and kept under observation for a period of 2 months.

Since plants of *Physalis floridana* Rydb. have been found to be more easily infected than other recommended indicator plants, Kirkpatrick (6), seedlings of this species were used as indicator plants in most tests. They were used in all tests with non-solanaceous species, and when positive recovery of virus was obtained, confirming tests were made with attempted transmission to additional seedlings of *P. floridana* and to seedlings of *P. angulata* L. and of *Datura stramonium*. In tests with solanaceous species, seedlings of *P. floridana* were usually used, often together with seedlings of one or both of the other indicator species. In a few cases, only *P. angulata, D. stramonium* or both were used. Attempted recovery of the virus was neglected only in the case of a few solanaceous species that showed diagnostic symptoms.

In general, the aphids fed with no apparent difficulty on the test species when the plants were young, hence unsuitability of a species as food-plant for the aphids was of minor importance during attempts to infect the seedlings. The plants were considerably older during the recovery tests and several species failed to support the aphids for 5 or 6 days. In some cases, repeated transfer of aphids to the test plants eventually resulted in the establishment of a new colony. Aphids were transferred from these colonies to the indicator plants. In others, it was necessary either to transfer the aphids to indicator plants after a 2-day feeding period or to transfer fewer than the usual number of aphids to the indicator plants.

Susceptible Species

Among the non-solanaceous species tested, only those within the families Amaranthaceae and Nolanaceae were found to be susceptible. On the other hand, most of the solanaceous species tested were found to be susceptible. The following species distributed among the indicated families were found to be susceptible to leafroll virus:

Amaranthaceae: *Amaranthus caudatus* L., *A. graecizans* L., *A. retroflexus* L., *Celosia argentea* L., vars. *childsii, cristata, plumosa* and *spicata.*, *Gomphrena globosa* L.; **Nolanaceae**: *Nolana lanceolata* Miers.; **Solanaceae**: *Atropa belladona* L., *Capsicum annum* L., *Datura Meteloides* DC., *D. tatula* L., *Lycopersicum esculentum* Mill., *L. pimpinellifolium* Mill., *Nicotiana affinis* Hort., *N. bigelovii* S. Wats, *N. clevelandii* Gray, *N. debneyi* Domin., *N. glutinosa* L., *N. nudicaulis* S. Wats, *N. repanda* Sims, *N. rustica* L., *Physalis lanceifolia* Nees, *P. longifolia* Nutt., *P. peruviana* L., and *P. pruinosa* L.

In addition to the susceptible solanaceous species listed above, many belonging to the genus *Solanum* proved susceptible as is shown in table 1. Because the taxonomy of these species is confused and many of the species identifications given are tentative and have not been authenticated by competent taxonomists, each collection is listed separately together with the numbers assigned to it by Dr. Donald Reddick and by the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture. Data also are given on the behavior of the aphids placed upon such plants. These data are assumed to be indicative of the suitability of the plants as suscepts for the aphids.

TABLE 1.—*Collections of Solanum species containing individual plants susceptible to leafroll virus.*

Species[1]	Collection Number		Number of Plants[4]	Behavior of Aphids[5]
	Reddick[2]	PI[3]		
S. capicastrum Link.			1/5	
S. carolinense L.			1/1	
S. citrullifolium A. Br.			1/5	
S. commersonii Dun.	169		5/5	M
	168		4/4	M
S. demissum Lindl.	1072		1/5	M
	1228	160,220	4/4	M
	1229	160,221	2/5	M
	1230	160,222	4/4	M
	1235	160,227	5/5	M
	1237	160,229	4/5	NM
	1238	160,230	3/3	M
	1239	161,149	3/5	M
	1253	161,153	3/5	M
	1254	161,154	2/4	M
	1255	161,155	2/5	NM,FR
	1263	161,163	5/5	M
	1264	161,164	4/5	M
	1265	161,165	4/5	M
	1266	161,166	3/4	M
	1267	161,167	5/5	M
	1269	161,169	5/5	M
	1275	161,175	5/5	M
	1276	161,176	4/4	M
	1279	161,179	5/5	M
	1281	161,181	1/2	NM,FR
	1285	161,365	5/5	M
	1286	161,366	3/5	M
	1287	161,367	1/2	MS
	1290	161,686	5/5	M

S. demissum Lindl.—*Cont.*	1291	161,693	4/4	M
	1294	161,725	4/5	M
	1298	161,729	5/5	M
	1300	161,731	1/5	M
	1301	161,155	3/3	NM
S. fendleri A. Gray			5/5[6]	
	167		3/3	M
S. garciae Juz. and Buk.			1/5[6]	
S. guerreroense Correll	1299	161,730	2/2	M
S. integrifolium Poir.			1/5	
S. jamesii Torr.			4/5[6]	
S. leptostigma Juz.			5/5[6]	
S. longiconicum Bitt.	1308		3/3	M
S. nigrum L.			3/5	
S. polyadenium Greenm.	1297	161,728	2/2	NM,FR
S. schickii Juz. and Buk.			4/5[6]	
S. tuberosum L. (*S. andigenum* Juz. and Buk.	1262	161,162	2/4	NM
	1282	161,182	5/5	M
	1305		5/5	MS
S. stoloniferum Schlecht.[7]	1232	160,224	1/3	NM,FR
	1233	160,225	3/3	NM
	1240	161,150	4/5	M
	1252	161,152	1/3	MS
	1258	161,158	2/2	NM,FR
	1260	161,160	4/4	NM
	1272	161,172	2/5	M
	1278	161,178	5/5	NM
	1283	161,281	5/5	NM
	1284	161,364	3/4	NM
	1303	161,770	3/3	NM
S. vavilovii Juz. and Buk.			2/5[6]	
S. verrucosum Schlecht.	569		4/4	M
	570		5/5	M
	1236	160,228	4/4	NM
	1273	161,173	3/3	M
	1274	161,174	4/4	M
	1295	161,726	3/3	M
S. spp.	1306		1/2	M

[1]Those species for which PI numbers are given are listed as identified by Correll (2). However, not all of the collections were from single plants and all plants from a given collection may not be identical with those examined by Correll. Those for which only Reddick's numbers are given were collected and identified by Reddick. Those without numbers were obtained by Reddick or by the authors from various sources. Those identified by Reddick's numbers and those without numbers have been carried under the names given without authentication by a competent systematist.

[2]Numbers under which the collections are filed in the files of Dr. Donald Reddick.

[3]U.S.D.A. Plant Introduction numbers (1).

[4]Numerator is number of plants infected. Denominator is number of plants tested.

[5]Behavior of the 5-7 non-viruliferous aphids placed on each test plant and left there 5-6 days. M indicates that the aphids multiplied, NM that they did not, MS that they multiplied on some plants and not on others, and FR that many of the aphids died and few were recovered.

[6]In these tests, recovery of the virus was not attempted. Those plants recorded as infected showed distinct symptoms.

[7]Considered by Correll (2) as a collective species. The collections listed under this name include those identified by others as *S. antipoviczii* Buk., *S. longipedicellatum* Bitt., and *S. neoantipoviczii* Buk.

Results with two species, *Nemophila menziesii* Hook. & Arn. (Hydrophyllaceae) and *Plantago major* L. (Plantaginaceae), were indeterminate. Two plants of the former species were used and the virus was recovered from both plants when *Physalis floridana* was used as the indicator species. However, the virus could not be recovered when either *P. angulata* or *Datura stramonium* was used. Positive results were obtained also on *Physalis floridana* with aphids from two plants of *Plantago major*. Repeated attempts to recover the virus from such plants were uniformly negative in tests in which *Physalis floridana, P. angulata* and *Datura stramonium* were used as indicator plants. It appears probable that stray aphids or other means of contamination may have caused the few infections observed and that *Plantago major*, at least, is insusceptible under the conditions used.

Species in Which Infection Was Not Established

Infection was not established in a few solanaceous species and many non-solanaceous ones. The following non-solanaceous species distributed among the indicated families were not susceptible to leafroll virus under the conditions used:

Apocynaceae: *Vinca rosea* L.; **Asclepiadaceae**: *Asclepias syriaca* L., *A. tuberosa* L.; **Balsaminaceae**: *Impatiens balsamina* L.[5]; **Bignoniaceae**: *Incarvillea* sp.; **Boraginaceae**: *Anchusa azurea* Mill., *A. barrelieri* Vilm., *Cynoglossum amabile* Stapf & Drummond, *Heliotropium arborescens* L.; **Campanulaceae**: *Campanula medium* L., *Wahlenbergia* sp.; **Capparidaceae**: *Cleome spinosa* L.; **Caryophyllaceae**: *Dianthus barbatus* L., *Gypsophila paniculata* L., *Saponaria officinalis* L.[5]; **Chenopodiaceae**: *Beta vulgaris* L., *Chenopodium album* L., *C. botrys* L., *C. hybridum* L.; **Compositae**: *Achillea millefolium* L., *Ambrosia artemisiaefolia* L., *Arctium lappa* L., *A. minor* Bernh., *Aster novae-angliae* L.[5], *Calendula officinalis* L., *Callistephus chinensis* Nees[5], *Chrysanthemum leucanthemum* L., *C. parthenium* Bernh.[5], *Cichorium intybus* L., *Gaillardia picta* Sweet., *Galinsoga parviflora* Cav.[5], *Helianthus annuus* L. *Heliopsis* sp., *Rudbeckia hirta* L., *Senecio aureus* L., *Solidago* sp., *Sonchus arvensis* L., *Tagetes lucida* Cav., *Taraxacum officinale* Weber, *Tithonia rotundifolia* Blake, *Zinnia elegans* Jacq.; **Convolvulaceae**: *Convolvulus arvensis* L., *C. purpureus* L., *Ipomea quamoclit* L.; **Cruciferae**: *Brassica oleracea* L. vars. *botrytis* L., *capitata* L., and *gemmifera* Thell., *B. rapa* L., *Matthiola incana* R. Br., *Nasturtium officinale* R. Br., *Raphanus sativus* L.; **Cucurbitaceae**: *Cucumis melo*. L.[5]; **Dipsacaceae**: *Dipsacus silvestris* Huds., *Scabiosa purpurea* Hort.; **Gramineae**: *Alopecurus pratensis* L., *Zea mays* L.; **Labiatae**: *Coleus blumei* Benth.[5], *Mentha arvensis* L.[5], *Salvia splendens* Ker-Gawl., Satureia sp.[5]; **Leguminosae**: *Cyamopsis psoraloides* D.C., *Lupinus perennis* L., *Medicago sativa* L.[5], *Pisum sativum* L., *Trifolium repens* L.; **Liliaceae**: *Trillium* sp.[5]; **Malvaceae**: *Althaea rosea* Cav., *Hibiscus esculentus* L., *Malva moschata* L.; **Onagraceae**: *Oenothera biennis* L.[5]; **Oxalidaceae**: *Oxalis corniculata* L.; **Papaveraceae**: *Eschscholzia californica* Cham., *Hunnemannia fumariaefolia* Sweet., *Papaver orientale* L.; **Phytolaccaceae**: *Rivina humilis* L.; **Plantaginaceae**: *Plantago lanceolata* L.; **Polemoniaceae**: *Cobaea scandens* Cav., *Phlox drummondii* Hook., *Polemonium* sp.; **Polygonaceae**: *Polygonum hydropiper* L.[5], *Rumex acetosa* L., *R. crispus* L.; **Portulacaceae**: *Portulaca oleracea*

L.; **Primulaceae**: *Lysimachia punctata* L.[5]; **Ranunculaceae**: *Aquilegia vulgaris* L., *Delphinium ajacis* L.; **Resedaceae**: *Reseda odorata* L.; **Rosaceae**: *Fragaria* sp.[5]; **Scrophulariaceae**: *Antirrhinum majus* L., *Chelone glabra* L.[5], *Cymbalaria muralis* Gaertn., Mey. & Scherb., *Digitalis purpurea* L., *Linaria vulgaris* Mill.[5], *Pentstemon* sp., *Verbascum thapsus* L.; **Tropaeolaceae**: *Tropaeolum majus* L.; **Umbelliferae**: *Daucus carota* L.; **Verbenaceae**: *Lantana* sp., *Verbena hybrida* Hort.; **Violaceae**: Viola sp.

The results of tests with species belonging to the family **Solanaceae** are listed separately in table 2. Because of the greater interest in the insusceptibility of solanaceous species, data indicative of the thoroughness of the recovery tests are also included. The results do not necessarily indicate immunity, but they do show that these species are highly resistant or non-susceptible when inoculated by means of aphids. It is apparent that several species, both solanaceous and non-solanaceous, are poor suscept plants for aphids. This fact doubtless is partly or wholly responsible for the negative results in some cases.

Symptoms

The most general symptom shown by susceptible non-solanaceous plants was a slight stunting. Infected plants of most of the Amaranthus species were stunted and the upper leaves became yellow, particularly at the base of the leaf. The lower leaves of infected plants of the Celosia varieties showed diffuse interveinal yellowing several months after inoculation. Infected plants of *Gomphrena globosa* were dwarfed slightly and the development of lateral branches was retarded. Infected plants of *Nolana lanceolata* were practically symptomless, although 3 of the 4 plants infected died prematurely. Whether this was because of the virus or of adverse effects of caging was not determined.

Symptoms shown by infected plants of solanaceous species were variable in intensity but similar in type. The most general symptoms were yellow blotching of the older leaves and stunting of the plant. Cupping or rolling of leaves was often present. Necrotic spotting of leaves and streaking of the stem were recorded only on plants of *Solanum demissum*, *S. jamesii*, and *S. fendleri*. The virus was lethal to some plants of *S. fendleri*.

Infected plants of the following solanaceous species were symptomless: *Atropa belladona*, *Capsicum annuum*, *Lycopersicon pimpinellifolium*, *Nicotiana glutinosa*, *N. rustica*, *Physalis peruviana*, *Solanum citrullifolium*, *S. integrifolium*, and *S. nigrum*. As adequate notes were not taken on some species, others of those listed in table 1 may also be symptomless carriers.

Discussion

The report by Salaman and Wortley (8) that Mätthiola, Campanula, turnip and Brussels sprouts are susceptible to leafroll virus was not confirmed. These two reports are not necessarily contradictory for different conditions were used and different species may have been used, for Salaman

[5]Aphids were not able to maintain themselves on these species for 5 days, consequently a 2-day feeding period was used.

TABLE 2.—*Collections of solanaceous species in which infection was not established or on which aphids died.*

Species[1]	Collection Number		No. Plants Tested[4]	Behavior of Aphids[5]	Recovery No. Plants[6]	Tests No. Aphids[7]
	Reddick[2]	PI[3]				
Datura metel L.			20		30	1
Physalis alkekengi L.			5		5	1
P. cotozmatl Moc. and Sesse			10		10	1
P. franchetii Mast.			5		5	1
P. pubescens L.			5		5	1
S. aculeatissimum Jacq.			5		20	1
S. cardiophyllum Lindl.	1307		1	M	2	2+
S. nigrum	M441		5		5	1
S. pseudocapsicum var. nanum Hort.			5		5	1
S. rantonnettii Carr.					5	1
S. sisymbrofolium Lam.			5		5	1
S. stoloniferum[8]	1234	160,226	3	NM,FR	3	1
	1241	161,151[9]	3	NM	3	1+
	1259	161,159	1	NM	2	2+
	1261	161,161[9]	1	NM,FR	1	1
	1271	161,171	4	M	8	2+
	1289	161,685[10]		NR		
S. suaveolens Kunth and Bouche	1288	161,368		NR		
S. spp.	M306		5		5	1
	1304		5	M	9	2+
	1310		1	M	2	2+

[1]See footnote 1, table 1.

[2]See footnote 2, table 1.

[3]See footnote 3, table 1.

[4]Number of plants from which recovery of virus was attempted .Where the number is less than 5 for species on which aphids did not multiply, recovery tests were not possible with some plants because of too few aphids.

[5]See footnote 5, table 1. The additional symbol NR indicates that all aphids died and none was recovered.

[6]Total number of indicator plants used in recovery tests: Plants of *Physalis floridana* were used in all cases except for *Datura metel* (10 *P. floridana*, 10 *P. angulata* and 10 *Datura stramonium*), *S. aculeatissimum* (10 *P. floridana* and 10 *P. angulata*), and *S. rantonnettii* (5 *P. angulata*).

[7]Number of aphids placed on each indicator plant. The figure 1+ indicates that 1 aphid was placed on each of 2 plants and 2-5 on another. The figure 2+ indicates that 2-5 aphids were used for each plant.

[8]Other collections of these species contained susceptible plants (Table 1).

[9]According to Correll (2), these collections also contained *S. demissum*.

[10]The plants tested appeared to be *S. polyadenium*.

and Wortley do not give specific names. Nevertheless, the results of the present investigation are interpreted as indicating that species in the families **Cruciferae** and **Campanulaceae** are not easily infected and are of little or no importance as overwintering hosts of leafroll virus.

Most of the common weeds and ornamentals found to be susceptible to leafroll virus are annuals. Since this virus has not been found to be seed-transmitted in any species, it is improbable that any annual serves as an overwintering host of the virus. However, a few susceptible

solanaceous species are perennials or are tuber-forming. Such species should be considered potential overwintering hosts in areas where they are common. Of these, *Solanum carolinense* is perhaps the most common suscept, for it is a common weed in many areas. This species has been listed as a food-plant for *Myzus persicae*, Patch (7).

The solanaceous species that appeared insusceptible should be tested further, for possibly some of them might be useful in potato-breeding programs. The present results mean only that these species were insusceptible under conditions which result in high percentages of infections in highly susceptible species. They may be immune, insusceptible to aphid-inoculation only, difficult to infect by aphid-inoculation, poor sources of the virus, or poor food-plants for aphids. Any of these properties might be of value in a potato variety, but the exact nature of the apparent insusceptibility should be known so that appropriate screening tests can be devised.

Those *Solanum* species in which some but not all plants became infected also warrant further consideration. For one thing not all of the collections were from single plants. Also, it is known that in the *demissum* group, as well as in some others, some plants from different localities or even from a single locality may show susceptibility to another disease (late blight, caused by *Phytophthora infestans* (Mont.) de Bary) whereas others show high resistance to or even immunity from the disease. Plants are known that are in a heterozygous condition in respect to blight. A similar situation might well exist with leafroll. Therefore, in the search for plants resistant to leafroll, a considerable number of individuals from collections from different localities should be tested, and greater importance given to the fact that some escape infection than to the fact that the collection contains some susceptible individuals.

Summary

The susceptibility to potato leafroll virus of over 150 species distributed among 39 families was determined. Inoculations were made by means of the peach aphid, *Myzus persicae*. The species considered susceptible are those from which the virus could be recovered 3 to 6 weeks following inoculation. Attempted recovery of virus was by means of aphids fed for 5 to 6 days on the test plants and then transferred to indicator plants, *Physalis floridana, P. angulata* or *Datura stramonium*.

Nine species in the family **Amaranthaceae** were tested and all were found to be susceptible. *Nolana lanceolata* was the only other non-solanaceous species definitely found to be susceptible. Of several solanaceous species tested, most were susceptible but a few were insusceptible under the conditions used. Infected plants of several solanaceous species were symptomless.

Literature Cited

1. Anonymous. 1948. List of plant materials introduced under direction of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Dept. of Agr., Project No. 111. Research and Marketing Act of 1946. Special Inventory No. 1 (Mimeographed)
2. Correll, D. S. 1952. Section *Tuberarium* of the genus *Solanum* of North America and Central America. Agricultural Monograph No. 11. U. S. Dept. of Agr. United States Government Printing Office. 243 Pp.

3. Dykstra, T. P. 1933. Weeds as possible carriers of leaf roll of rugose mosaic of potato. Jour. Agr. Res. 47: 17-32.

4. Helson, G. A. H., and D. O. Norris. 1943. Transmission of potato virus diseases III. Susceptibility of Cruciferae to potato leafroll virus. Jour. Coun. Sci. Indus. Res. (Australia), 16: 261-262.

5. Hovey, C., and R. Bonde. 1948. *Physalis angulata*, a test plant for the potato leafroll virus. Phytopath. 38: 505-507.

6. Kirkpatrick, H. C. 1948. Indicator plants for studies with the leafroll virus of potatoes. Amer. Potato Jour. 25: 283-290.

7. Patch, Edith M. 1938. Food-plant catalogue of the aphids of the world. Including the Phylloxeridae. Maine Agr. Exp. Sta. Bull. 393.

8. Quanjer, H. M. 1923. General remarks on potato diseases of the curl type. Internat. Conf. Phytopath. and Econ. Ent. Rpt. 1923: 23-28.

9. Ross, H. and M. L. Baerecke. 1950. III. Selection for resistance to mosaic virus (diseases) in wild species and in hybrids of wild species of potatoes. Amer. Potato Jour. 27: 275-284.

10. Salaman, R. N., and W. R. S. Wortley. 1939. Potential hosts of potato viruses in garden and field. Nature 144: 1049-1050.

11. Stelzner, G. Virusresistenz der Wildkartoffeln. 1950. Zeit. f. Pflanzenzchtg. 29: 135-158.

RESISTANCE OF SOME AMERICAN POTATO VARIETIES TO THE LATE BLIGHT OF POTATOES[1]

L. C. PETERSON[2] AND W. R. MILLS[3]

It is now well over a century since the late blight of potatoes struck almost simultaneously with such devastating results on the European and the North American continents. Because of its destructive potentiality, and the economic importance of the potato as a food crop, an intensive search was initiated for the cause and means of control of the new potato disease. Progress, at first, was naturally slow. It had not been determined that fungi could cause a diseased condition in plants. In fact, it was commonly accepted in the scientific circles of the time that the fungus always associated with the new disease of the potato was not the cause but rather the result of a diseased condition. With this type of thinking it was wholly logical to attribute the cause of the potato disease to unwholesome weather conditions during the growth of the plant, or to a degeneration of the potato as a result of continued vegetative propagation by the use of tubers. This last theory, although perhaps amusing in the light of present knowledge, was, nevertheless, very important. It stimulated the importation and propagation from seed of varieties from South America, the home of the potato, in the hope that vigor could be regained by growing plants from true seed. For all practical purposes, this was the beginning of the development of resistant varieties — *i.e.*, the search for a usable source of resistance in existing varieties.

The outstanding early American potato breeder who subscribed to the above theory was the Rev. Mr. Chauncey E. Goodrich of Utica, New York. Through the consular service in South America, Goodrich imported several varieties of potatoes. Although he failed to find blight resistance, his influence on subsequent potato breeding in the United States was extensive. He definitely showed that improved varieties could be produced by plant breeding methods (7). From an imported variety which he called Rough Purple Chili, the Rev. Mr. Goodrich produced the seedling Garnet Chili. This variety, in turn, is one of the progenitors of several of the older American varieties, including Early Rose, Early Ohio, Prolific, Triumph and perhaps even the Irish Cobbler (3).

Resistance to late blight was not entirely lacking among the American varieties. Evergreen is an outstanding example. This variety, in a numerical classification of resistance from 1 to 4, with 4 representing the most susceptible class, was rated as 3 and sometimes as 2 (7). Evergreen, also known by such names as No Blight and Blight Proof, has persisted for years in Central New York, where, because of its blight resistance and good cooking quality, was grown mainly for home consumption. With the appearance of new, high yielding varieties and improved methods of late blight control, the popularity of Evergreen has greatly diminished.

Within relatively recent years, we have witnessed the introduction

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of a large number of new potato varieties. This influx is largely due to the breeding programs of the United States Department of Agriculture, the various State Experiment Stations and the combined efforts of the two groups cooperating in the National Potato Breeding program.

Of these new varieties, a few possess somewhat more resistance to late blight than the older American varieties as is shown in table 1. In this general group may be mentioned such varieties as Sebago (15), Sequoia (5), the scab-resistant varieties Menominee (18), Ontario, Seneca and Cayuga (2), Potomac (6), Saranac (16) and the variety Calrose (4). The resistance of these varieties to late blight is not enough, however, to warrant their cultivation without the use of a protective fungicide.

In addition to slight foliage resistance to late blight, the variety Sebago possesses a degree of resistance to the disease in its tubers. Cases have been reported, however, (13) in which tuber rot with the variety Sebago exceeded that in the susceptible variety Russet Rural. This situation is likely to occur when varieties possessing some resistance to *Phytophthora infestans* are grown under conditions favorable for the development of late blight and are not thoroughly protected by a fungicide. The susceptible varieties are rapidly killed by the disease. The more resistant varieties, although infected, live and shower the ground about them with spores over a longer period of time, thus greatly increasing the possible chances for tuber infection.

Thousands of potato importations have been made from South America over the last century. It is significant that in all of these importations no resistance to late blight was found. Likewise, over a period of years thousands of seedlings have been produced as the result of

TABLE 1.—*Relative susceptibility of a few American potato varieties to the common race of Phytophthora infestans (Mont) deBary.*

Variety	Susceptibility Rating
Green Mountain	+ + + +
Russet Rural	+ + + +
Evergreen	+ + +
Calrose	+ + +
Cayuga	+ + +
Menominee	+ + +
Ontario	+ + +
Potomac	+ + +
Saranac	+ + +
Sebago	+ + +
Seneca	+ + +
Sequoia	+ + +

+ + + + = Complete susceptibility

intercrossing our old American potato varieties and none has exhibited a very marked resistance to late blight. The conclusion seems warranted that satisfactory resistance to *P. infestans* is lacking in the species *Solanum tuberosum* or the closely allied species *S. andigenum*. Reddick (8), searching for a source of resistance to the late blight organism among the tuber-forming species of the genus *Solanum*, confirmed Salaman's discovery that *S. demissum*, a wild potato from Mexico, is immune from *P. infestans*. Unfortunately, this species is horticulturally worthless. The plants are very late in maturing and produce small, deep-eyed tubers at the ends of stolons which are from 3 to 4 feet long. Although *S. demissum* possesses 72 chromosomes and our potato varieties only 48, crosses were effected when *S. demissum* was used as the female parent. It was found that resistance to late blight is a heritable character. Further crossing with other American varieties eventually produced seedlings which were immune from the common form of *P. infestans* and at the same time horticulturally acceptable as potato varieties. The variety Empire was introduced in 1945 (10); the varieties Placid, Virgil, Ashworth and Chenango in 1947 (11); and Essex, Glenmeer, Madison, Snowdrift, Fillmore, Harford, and Cortland in 1950 (12). A few years later, the United States Department of Agriculture released the variety Kennebec (1) and recently, in cooperation with the State of Virginia and the States of Iowa and Indiana, the varieties Pungo (14) and Cherokee (17). Although the source of resistance used in these last three varieties was seedlings obtained from Germany, the breeding behavior of Kennebec and Cherokee and their reaction to the various races of *P. infestans* strongly suggest that the resistance factor present in these varieties was originally inherited from *S. demissum*.

It has become increasingly apparent over the past few years that *P. infestans* is a very variable organism. Recent developments concerning the biology of this organism have and will continue to affect the future development of blight-resistant potato varieties. *Phytophthora infestans* is propagated by asexually formed swarmspores. Theoretically at least, every spore formed, with minor exceptions, should be exactly like its neighbor. Under these conditions, a large number of pathogenic races within *P. infestans*, such as occur in the organism which causes the rust of wheat, was not anticipated. However, several such races have been found.

There is a considerable amount of evidence which indicates that under normal field conditions *P. infestans* does not actually exist as a composite of a large number of races. In 1933, Reddick and Crosier (9) were unable to demonstrate any difference in the pathogenicity of cultures of *P. infestans* obtained from widely separated localities in the United States, Canada and Prince Edward Island. Likewise, in a survey recently made in the major potato producing areas of New York State, only the existence of the common race of *P. infestans* could be demonstrated. On the other hand, new races have been found on resistant selections grown adjacent to a planting of susceptible varieties when conditions were extremely favorable for the development of late blight. Within the limits of our experience, such infection is invariably first noted on the resistant varieties weeks and even months after its first appearance on susceptible varieties. If a mixture of races existed under field conditions, even if in disproportionate amounts, a few lesions, at least, should have appeared on some of the resistant varieties at approximately the time the susceptible varieties

were generally infected. Many isolations of the pathogen have been made from such infected seedlings. All isolates varied from the common race of *P. infestans* in that they were capable of infecting many seedlings not infected by the common field race. On the basis of pathogenicity tests, all of the isolates could be placed into one of five separate groups. Races B, C, D, BC and BD of *P. infestans*, each distinct from the common field race A, have been identified.

A possible explanation for the sudden appearance of new races of *P. infestans* where they hitherto had not existed involves a change taking place both in the pathogen and in the resistant seedlings. Greenhouse experiments have demonstrated conclusively that the first appearance of blight on some of the resistant varieties late in the growing season is correlated with the physiological maturity of the plant. In some cases, infection may take place only after the plant becomes senescent. Infection in such cases may first appear as tiny necrotic specks or as active lesions. The organism isolated from the active lesions invariably is capable of causing infection on young, vigorously growing plants of the seedling or variety in question. Thus, a new race of *P. infestans* has been produced capable of easily infecting a plant which is immune from the common form or field race A of the pathogen. In rare cases, the same change has been known to take place suddenly under greenhouse conditions. The mutant spore, or the new form, thus produced is capable of causing infection immediately on young, vigorously growing plants which are immune from the parent culture. In either of these cases, a change takes place in the pathogen. If the new form comes in contact with a resistant plant, the latter not only makes possible the detection of the new form of *P. infestans*, but also provides suitable conditions for its multiplication without competition from the common field race. Races that have been produced by these means under controlled conditions in the greenhouse from the common field race of the pathogen are identical with the five new races isolated from field-grown plants.

Without exception, all of the recently introduced blight resistant varieties are susceptible to races D and BD of the pathogen and are immune from all others (Table 2). In addition, the tubers of some of these varieties are said to be resistant to the common form of blight but they are readily susceptible to these two new races of *P. infestans*. This fact has an extremely important bearing on the survival of the new races of the late blight organism from one season to the next.

The new races of *P. infestans* have not, until recently, become generally prevalent in commercial fields of potatoes. However, in early July, 1949, very severe blight was observed in a field of Essex potatoes, in Somerset County, Pennsylvania. This field was planted from the grower's own seed, in which blight had been observed the previous autumn by a State inspector. By the end of the season, blight had spread to many small plantings of Essex in that area. Although blight-resistant varieties grown in Pennsylvania today are sprayed similarly to susceptible varieties, the number of reports of blight in these varieties leads to the belief that race D is now generally prevalent.

In certain sections of the country, the weather conditions are such that late blight does not make an annual appearance and then only rarely does it occur in severe, destructive proportions. Under such conditions, the

TABLE 2.—*Resistance of some newly introduced American potato varieties to five races of Phytophthora infestans (Mont) deBary*

Variety	Race of *P. infestans*					
	A	B	C	D	BC	BD
Ashworth	—	—	—	+	—	+
Chenango	—	—	—	+	—	+
Cortland	—	—	—	+	—	+
Empire	—	—	—	+	—	+
Essex	—	—	—	+	—	+
Fillmore	—	—	—	+	—	+
Glenmeer	—	—	—	+	—	+
Harford	—	—	—	+	—	+
Madison	—	—	—	+	—	+
Placid	—	—	—	+	—	+
Snowdrift	—	—	—	+	—	+
Virgil	—	—	—	+	—	+
Cherokee	—	—	—	+	—	+
Kennebec	—	—	—	+	—	+
Pungo	—	—	—	+	—	+

+ = susceptibility
— = immunity

resistance of varieties like Kennebec and Essex, for example, may be sufficient to protect the variety for years — even to the extent of omitting protective sprays. This, however, would be dependent upon planting seed which is free from blight infection, for infected tubers provide ideal means for the distribution of the new races of *P. infestans* from one area to another. For this reason the resistant varieties should be sprayed in seed-growing areas, even though the new races have not been observed.

LITERATURE CITED

1. Akeley, Robert V., F. J. Stevenson and E. S. Schultz. 1948. Kennebec: a new potato variety resistant to late blight, mild mosaic and net necrosis. Amer. Potato Jour. *25*: 351-361.
2. Blodgett, F. M. and F. J. Stevenson. 1946. The new scab-resistant potatoes, Ontario, Seneca and Cayuga. Amer. Potato Jour. *23*: 315-329.
3. Clark, C. F. and P. M. Lombard. 1946. Descriptions of and key to American potato varieties. U.S.D.A. Circ. No. 741.
4. ———. 1946. The Calrose potato: a new variety possessing resistance to late blight. Amer. Potato Jour. *23*: 343-347.
5. Gardner, M. E., Robert Schmidt and F. J. Stevenson. 1945. The Sequoia potato: a recently-introduced insect-resistant variety. Amer. Potato Jour. *22*: 97-103.
6. Jehle, R. A. and F. J. Stevenson. 1945. The Potomac potato. Amer. Potato Jour. *22*: 261-266.

7. Reddick, Donald. 1928. Blight-resistant potatoes. Phytopath. 18: 483-502.
8. ———. 1930. Frost-tolerant and blight-resistant potatoes. Phytopath. 20: 987-991.
9. ——— and Willard Crosier. 1933. Biological specialization in *Phytophthora infestans*. Amer. Potato Jour. 10: 129-134.
10. ——— and L. C. Peterson. 1945. Empire — a blight-resistant variety. Amer. Potato Jour. 22: 357-362.
11. ——— and ———. 1947. New blight-resistant varieties. Amer. Potato Jour. 24: 319-336.
12. ——— and ———. 1950. Additional blight-resistant varieties. Amer. Potato Jour. 27: 1-10.
13. Rieman, G. H. and J. S. McFarlane. 1943. Severe potato late blight infection in Sebago tubers. Phytopath. 33: 1104-1106.
14. Salter, Robert M. and Victor A. Tiedjens. 1951. New varieties released — Pungo. Amer. Potato Jour. 28: 641.
15. Stevenson, F. J. and C. F. Clark. 1938. The Sebago potato, a new variety resistant to blight. U.S.D.A. Circ. No. 503.
16. ——— and J. R. Livermore. 1949. The Saranac potato, a new variety promising in Australia. Amer. Potato Jour. 26: 33-46.
17. Stewart, George F., N. J. Volk and R. M. Salter. 1951. New varieties released —Cherokee. Amer. Potato Jour. 28: 642-643.
18. Wheeler, E. J., F. J. Stevenson and H. C. Moore. 1944. The Menominee potato: a new variety resistant to common scab and late blight. Amer. Potato Jour. 21: 305-311.

RELATION OF TIME OF PLANTING POTATOES TO TUBER FLEA BEETLE ATTACK IN NEBRASKA AND WYOMING[1]

R. L. Wallis[2]

The tuber flea beetle is a serious enemy of potatoes in some of the western States. It is particularly injurious to early-planted potatoes grown under irrigation in Colorado, Wyoming, and Nebraska. The adult flea beetles feed on the leaves and make numerous small holes in them, and the larvae feed on the tubers and make tunnels along the surface, a condition known as worm track. Sometimes the larvae penetrate the tubers to a depth of a quarter inch, causing pimples or slivers.

From 1945 to 1951 the writer made observations in the North Platte Valley of Nebraska and Wyoming on the relation between tuber flea beetle abundance and the time of planting of commercial crops of potatoes.

Several workers have observed a difference in injury between early and late plantings of potatoes. Swenk and Tate (1940) in Nebraska reported that potatoes planted before June 10 are far more likely to be damaged than those planted later. According to Hoerner and Gillette (1928) in Colorado, growers say that worm track can be avoided by postponing planting until the middle or latter part of June. Hill (1941) recommended that early potatoes should not be planted in western Nebraska in localities where flea beetle injury commonly occurs, and that late potatoes should be planted as late in the season as possible. Hill and

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Tate (1942) showed that flea beetle populations develop earlier and reach a higher peak on potatoes planted approximately April 26 - 28 than on later plantings. They are also more severe on potatoes planted June 2 than on those planted about June 20.

Methods

Counts of beetles were made by the sweep-net method at weekly intervals during the growing period. A 15-inch insect net was brushed briskly across the tops of the plants, which were allowed to cover approximately half of the net opening. From one to four 100-sweep samples were taken at each observation.

From eight to ten observation points were established at random for each of the three plantings of potatoes. The early crop, which covers less than 5 per cent of the acreage planted to potatoes in this area, is planted in late April and early May, and the commercial late crop from approximately May 25 to June 30. To determine whether there was a difference in populations on the earlier and later parts of the late crop, sampling was done on fields planted from May 25 to June 10 and on those from June 20 to 30, which were designated as medium and late plantings, respectively. The early crop of potatoes is harvested in August, and the medium and late crops at approximately the same time, in late September and early October.

Results

The results of these counts are shown in table 1. Each season the numbers of flea beetles were highest on the early crop and higher on the medium than on the late crop. The population on the medium crop averaged only 37 per cent and that on the late crop 6 per cent as high as that on the early crop. The population on the late crop was only 17 per cent as high as that on the medium crop.

TABLE 1.—*Numbers of tuber flea beetles per 100 sweeps on early, medium, and late plantings of potatoes.*

Year	Early	Medium	Late
1945	33.9	2.0	1.2
1946	20.8	3.3	.4
1947	6.5	.8	.1
1948	39.0	11.9	2.6
1949	14.4	10.0	.9
1950	22.6	17.3	3.3
1951	43.1	20.9	2.7
Mean	25.8	9.5	1.6

The reason for the higher population on the early plantings is not well known. In the spring when the beetles emerge from hibernation, the early crop is generally present, and during the hot weather of mid-summer the flea beetles, which may move from wild host plants, appear to prefer the larger plants of the early crop. Hill and Tate (1942) showed that, although potatoes and potato sprouts in cull piles are the most important spring hosts of flea beetles in western Nebraska, large numbers may be found on alfalfa and weeds along irrigation ditches in May and June, smaller numbers in July and August, followed by a rapid increase again in September.

A considerable acreage of potatoes is planted in western Nebraska and eastern Wyoming as late as June 30, and yields are as high as from early June plantings and much higher than on April and early May plantings.

Summary

It is obvious that late planting is a good means of protecting the potato crop from flea beetle attack. The later the crop can be planted with assurance of sufficient time to bring it to maturity, the less likelihood of serious beetle injury. Infestations on late plantings may be further reduced by applying insecticides on the early crop. The elimination of potato sprouts growing in cull piles, the destruction of weed hosts, and the omission of the early crop in areas, where practical, will also reduce spring populations, which would be a menace to late potatoes.

Literature Cited

1. Hill, Roscoe E. 1941. Potato flea beetle development and its relationship to control in the North Platte Valley. Nebr. Potato Improvement Assoc. Rpt. 22, p. 5.
2. ———, and H. Douglas Tate. 1942. Life history and habits of the potato flea beetle in western Nebraska. Jour. Econ. Ent. 35 (6) : 879-884.
3. Hoerner, John L., and C. P. Gillette. 1928. The potato flea beetle. Colo. Agr. Exp. Sta. Bull. 337.
4. Swenk, Myron H., and H. Douglas Tate. 1940. The potato flea beetle and the potato psyllid in Nebraska. Nebr. Agr. Exp. Sta. Bull. 327.

RESISTANCE OF POTATO VARIETIES TO CHARCOAL ROT[1]

M. J. THIRUMALACHAR AND PUSHKARNATH

Charcoal rot of potato incited by *Macrophomina phaseoli* (Maubl.) Ashby is fairly widespread in the potato growing regions of Bihar, Uttar Pradesh and few other places in India. The damage caused by the fungus may range from 5 to 70 per cent depending upon the presence of the pathogen in the soil, susceptibility of the variety and occurrence of predisposing conditions. The warm weather conditions and consequent rise in soil temperature are the chief predisposing factors Thirumalachar, (4). As described by Littauer (1) in Palestine, the loss caused by the disease may be only 5 per cent at the time of lifting of tubers but may gradually increase to 50 per cent during storage.

In controlling charcoal rot disease, cultural practices such as early harvesting before the onset of hot weather conditions are helpful in reducing the percentage of infection. Although these may to some extent offer means of avoiding the disease, the ultimate object of securing resistant varieties is very desirable. Even though no potato variety is known to be resistant to charcoal rot at the present time, resistance to this disease has been reported in a few other crop plants. Varieties of corn, Young, (6), California Blackeye No. 1 cowpeas, Mackie, (2), and Blackeye No. 8142 cowpeas, Young, (5), have been reported to be resistant to *M. phaseoli* infection. Further, Young, (7), reported that the *Giant Striata* variety of *Crotalaria*, Johnson grass, guar and German millet are immune to charcoal rot disease.

Studies on the possibility of the existence of varietal resistance in potato varieties to charcoal rot infection were started at the Central Potato Research Institute, Patna, with a view to secure resistant varieties which may be utilized in commercial cultivation of the crop or used in further breeding work. In this process two lines of investigations are under way, one of them being the growing of varieties in infected soil under condition favorable for the fungus and thus assessing their resistance to the disease in the field. The second line of work, which is being reported in this paper, refers to the assessing of genetic resistance or immunity of varieties by conducting artificial inoculation of tubers in the laboratory employing pure cultures of the fungus. The degree of resistance was determined and classified in 4 categories which are indicated by numbers: O—immune, I—resistant, II—moderately susceptible, and III—very susceptible. The descriptions of these different reactions will be given later.

MATERIALS AND METHODS

The materials for these studies were obtained from the Simla Station of the Central Potato Research Institute where a large number of potato collections* are being maintained. The potato varieties consisted of 18

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[2]Central Potato Research Institute, Patna, Bihar, India.

*Varieties designated as "Exotic commercial" were secured from U.K., U.S.A. and Holland. Chilean *S. tuberosum* varieties were secured partly from Commonwealth Potato Collection, Cambridge, and partly from Russia.

Indian varieties, Pal and Pushkarnath, (3), 330 exotic collection of commercial varieties, clonal lines of Chilean *Solanum tuberosum,* exotic hybrids, clonal lines of *S. andigenum,* and a few South American tuber-bearing *Solanum* species that were available. Single plant lines of an interspecific hybrid of *S. commersonii* group which has good tuber-bearing qualities and is being studied at the Central Potato Research Institute were also tested for resistance to *M. phaseoli.* The testing of this interspecific hybrid has an additional interest because the plants are capable of developing tubers even after the commencement of summer months when the chances of tuber infection by *M. phaseoli* are at a maximum.

For inoculating the tubers, the following procedure was followed; forty-eight hours' old cultures of the fungus grown in Petri dishes and incubated at 32°C. were used for inoculation. The fungus grew very rapidly and covered the plate within 24 hours developing large strands of hyphae. The tubers to be inoculated were first surface-sterilized with 95 per cent ethyl alcohol for a few minutes. A small puncture of 1 to 2 millimeters deep was made with a sterilized needle and the inoculum consisting of strands of hyphae taken from the margin of the colony was inserted inside the punctured tuber surface. The inoculated point was sealed off with paraffin wax. The inoculated tubers were incubated at room temperature during the months of May and June (28 - 30° C.) or placed in an incubator at 30°C. during other months when room temperature was relatively cool. In controls, the tubers were only punctured with a sterilized needle and sealed off with paraffin wax. This method of inoculation has been found to be very successful yielding 98 to 100 per cent infection. Tubers that failed to show infection after the 10th day were re-inoculated twice again to confirm their resistance to the disease. Observations were taken on the 2nd, 5th and 10th day after inoculation. The results of the inoculation tests are presented below and the different varieties are classified according to the degree of resistance.

I. *Varieties showing III-type of Reaction* (Very susceptible).
Indian Commercial Varieties:

Darjeeling Red Round, Ben Crauchan, Early Rose, Gola B, Gola C, Great Scot, Helora, Italian White Round, Majestic, Magnum Bonum, Northern Star, Phulwa, Phulwa purple splash, Red Long Kidney, Red Rocks, Royal Kidney, Sathoo, Up-to-Date.

Exotic Commercial Varieties:

Abundance, Adirondock, Adina, Allion, Allanah, Ally, Anna, Angus Leader, Arran Banner, Arran Chief, Arran Counsul, Arandale, Arran Chest, Arran Victory, Arran Favorite, Arran Pilot, Arran Signet, Arran Rose, Arran White, Arran Viking, Arran Peak, Barron, Benalt, Ballydoon, Blacksmith, Blue Flower, Bintje, Bishop, Beauty of Bute, Belladoon, Benest, Blue Gloss, Bobbie Burns, Bressie, Buchan Beauty, Brown Rocks, Bishop, Canns, Carick Rogue, Cardinal, Catrriona, Centifolium, Clark's Seedling 650, Clark's Seedling 832, Chippewa, Claymore, Champion, Crusader, Craig's Defiance, Conquest, Dargill Early, Dean ,Delaware, DiVernon, Doon Eire, Doon Star, Doon Pearl, Dunbar Standard, Dunbar Rover, Desota, Denmarg, Duke of York, Dumfries Rogues, Early Market,

Early Regent, Early Wonder, Earl of Sussex, Eclipse, Ekshirazu, Edgecote Purple, Electron, E. P. Champion, Epicure, Elsa, Era, Erlaine-1, Erlaine-2, Factor, Fite Rogue, Flourball, Flounder, Gigantic, Gladstone, Glasgow Favorite, Gloss Rogue, Green Mountain, Herald, Heinkul, Home Guard, Immune Ashleaf, Imperia, International Kidney, Invernes Favorite, Irish Cobbler, Irish Queen, Isle Star, John Bull, Katahdin, Katie Glover, Keppelstone Kidney, King Edward, King George, Karana, Kerr's Pink, Longworthy, Lymm Grey, Mighty Atom, Mesaba, Mackelvies 303/18, Mackelvies 298/5, Mackelvies 304/83, Magnificent, Marquis of Bute, Muller's 23/31, Monshine, Ninety Fold, New Aberdinian, Night Shade, Nurnhead Rogue, Norna, Oran Beauty, Orange Anther Substitute, Peach Blossom, Pawnee, Pink-Fir-Apple, Placid, Pontiac, President, Prize Taker, Queen of Veldt, Red King, Red Skin, Red Rocks, Response, Robygen, Rural Russet, Red Warba, Sarang, Satapa, Sequoia, Sebago, Shamrock, Skerry Blue, Sharp's Express, Southesk, Sutton's Seedling 10/30/3, Strathmore Glory, Snow Drops, Temper, Teton, The Isle, Tinwald Perfection, U. S. Seedling 41956, Up-to-Date (Bald's Early-1), Up-to-Date (Bald's Late-2), Ulster Cromleck, Ulster Chieftain, Ulster Commerce, Ulster Earl, Ulster Ensign, Utility, Village Blacksmith, Virgil, Warba, Waverley, White Forty-Fold, Wild Rose, Windsor Castle, Yankee Babe, Yam. Chilean *S. tuberosum* C.P.S. numbers 516, 518, 519, 521, 522 to 528, 534, 535, 536, 539 to 545, 547, 553 to 559, 563, 564, 567, 568 to 574, 576, 577, 578, 583 to 585, 588, 591, 592, 594, 596, 598, 601. Exotic hybrids C.P.S. numbers 609, 611 to 617, 620 to 623, 627 to 637, 639, 644, 645, 647, 650, 653, 654. *Solanum andigenum* C.P.S. numbers 656, 659 to 662, 666, 671, 673, 676, 678 to 684, 687, 688, 690, 693, 697, 701, 703, 704, 713, 717, 718, 720, 721, 730, 731, 734 to 739, 741 to 743, 747, 751 to 753, 757, 759, 761, 762, 765, 767, 773, 780, 781, 786, 788, 791, 796, 800 to 804, 806 to 810, 814, 816 to 818, 827, 828, 832, 839. *Hybrids evolved at Central Potato Research Institute* O.N.45, 119, 149, 208, 209, 249, 291, 293, 295, 567, 610, 639, 642, 754, 764, 769, 770, 810, 819, 874, 991, 1070, 1134, 1147, 1151, 1160, 1187, 1202, 1280, 1137, 1360, 1142, 1661, 1734, 1952, 1196, 2090, 2145, 2186, 2234, 2236, 2253, 2267, 2287, 2818, 2285, 2891, 2898, 3222, 3529, 3695, 3883, 3894, 3998 and 4184.

South American species of Solanums: Solanum curtilobum, S. ascasabii, S. kesselbrenneri, S. demissum, S. rybinii, S. jamesii.

II. *Varieties showing II-type of reaction* (Moderately susceptible) Saskia, C.P.S. 585 (Chilean *S. tuberosum*), C.P.S. 831 (*S. andigenum*).

III. *Varieties showing I-type of reaction* (Resistant)
Mackelvies 305/50, *S. andigenum* (C.P.S. numbers 797, 798).

IV. *Varieties showing O-type of reaction* (Immunity)
Single plant selections of the interspecific hybrids between species belonging to series *Commersoniana* numbers 16-2, 9-18, 8-2, 20-1, 9-20, 23-3, 9-10, 9-6, 19-2, 15-1, 17-3, 20-3, 8-1, 9-12, 16-10, 9-8, 16-4 and 13-4.

The table indicates that a large number of varieties are very susceptible to charcoal rot infection. Observations made after two days show a wet rot type of infection 5 to 10 mm. in diameter from the point of inoculation. Within 5 days the entire tuber becomes infected showing the blackening

of lenticels and killing of eye buds. The tuber tissue becomes discolored exuding an amber colored liquid or gets converted into a mash if accompanied by secondary organisms. In varieties like *Phulwa, Helora, Darjeeling Red Round* which also show III-type of reaction, the invasion of the tubers by the organism is comparatively slow.

In Saskia and C.P.S. 585 and 831 which show II-type of reaction *viz.*, moderate susceptibility, the first sign of infection is not perceptible until 7 or 8 days after inoculation and the progress of disease spread within the tuber is rather slow. Apart from the blackening of lenticels, the progressive killing of the eyes is a good external symptom for indicating the progress of the pathogen. In the case of Saskia and the other two varieties showing II-type of reaction, the tubers in some cases showed only partial infection, many of the eye buds remaining alive and green.

The resistant type of reaction (I-type) has been observed so far only in 3 of the varieties mentioned in the above table. C.P.S. 797 and 798 are *S. andigenum* varieties, while Mackelvies seedling 305/50 is a *S. tuberosum* variety. In these three varieties the tubers were inoculated 6 to 7 times and in every case the same type of reaction was noticed. Observations made 10 days after inoculation revealed no symptom of the disease. Cutting through the tuber at the point of inoculation showed no discoloration or advance of the hyphae. Following this, the tubers were inoculated and incubated at 30°C. for 25 days and more. Observations made after this prolonged incubation showed only slight depressions at the points of inoculation. After cutting through the tuber, the following interesting observation was made. From the point of inoculation the fungus had advanced 2 to 3 mm. and all the diseased tissue had collapsed into a dry powdery mass leaving a small cavity. Between the infected and healthy tissue, a black crustose mass resembling a ring in sectional view, had been formed. These on examination proved to be the sclerotia of the fungus.

Preliminary studies on the host-parasite relations in the susceptible and resistant varieties have shown that in the case of susceptible and moderately susceptible types of reactions, the hyphae are inter-cellular, rapidly penetrating into the tuber tissue and often inciting the dissolution of the middle lamellae and separation of the host cells. The contents of the host cells become brown and deprived of starch. Few thick-walled hyphae are formed within the tuber tissue, but no sclerotia are produced. In contrast, in the three resistant varieties noted in the present study, the advance of the hyphae is prevented by mechanical resistance in the form of the collapse of the host cells, comparable to the necrotic reaction seen in the case of leaves showing resistance to rust infection. Because of unfavorable host reaction and possibly owing to the failure of establishing and obtaining nutrition from the host cells, the fungus forms the resting stage, *viz.*, thick-walled sclerotia. The collapse of the host cells and the formation of a thick band of sclerotia only a few millimeters away from the point of inoculation indicate the active type of resistance of the host to the pathogen.

The O-type of reaction which indicates immunity of the host has been noticed only in the case of certain clonal lines of the interspecific hybrid belonging to the series *Commersoniana.* In these clonal lines repeated inoculations and prolonged incubation over 30 days failed to manifest any

symptoms of the disease. After cutting through the tuber and making an examination at the point of inoculation it was evident that the hyphae which had been used as inoculum had collapsed and the fungus had failed to establish itself as a pathogene. Field observations also confirmed the fact that though the tubers had been allowed to remain in the field during the month of April when the air temperature was about 40° during day time and soil temperature above 50°C. there was no disease incidence because of charcoal rot. Further studies are being made at the Central Potato Research Institute to obtain clonal selections of this interspecific hybrid which would show immunity to charcoal rot and at the same time possess good tuber qualities approaching commercial standards.

Literature Cited

1. Littauer, F. 1944. *Sclerotium bataticola* on potatoes in Palestine. Palestine Jour. Bot. Rehovot Ser. 4: 142-147.
2. Mackie, W. W. 1946. Blackeye beans in California. Cal. Agr. Exp. Sta. Bull. 696.
3. Pal, B. P. and Pushkarnath. 1951. Indian potato varieties. Indian Council Agr. Res. Bull. 62: 1-63.
4. Thirumalachar, M. J. 1952. Charcoal rot of potatoes in Bihar. Proc. Indian Sci. congr. 1952 (Abstr.)
5. Young, P. A. 1942. Blackeye pea No. 8152 resistant to root knot. Texas Agr. Exp. Sta. Ann. Rept. 55: 33.
6. ———. 1949a. Symptoms and resistances of crop plants to charcoal rot and ashy stem blight. Phytopath. 39: 27 (Abstr.)
7. ———. 1949b. Charcoal rot of plants in east Texas. Texas Agr. Exp. Sta. Bull. 712: 1-33.

ANNOUNCEMENT

With this issue of the American Potato Journal we start a new section to be devoted to our farmer members and others who are not particularly interested in the specialized scientific papers usually published.

We hope to maintain this section as a monthly feature. However its frequency will depend upon our ability to secure suitable articles.

Popular articles on many phases of potato production and marketing in various parts of the United States and foreign countries will be published from time to time.

Suitable articles written by our readers will be welcomed. We would also be glad to hear from our readers regarding the types of articles you would like to see.

News items from any section of the country that might be of interest to potato growers in general are requested. However we cannot pay for such items.

John Campbell
Associate Editor

POTATO NEWS AND REVIEWS

PALLETIZED HANDLING AND STORAGE OF POTATOES

SAM KENNEDY[2]

Let me say to start with that our pallet system is tied in directly with mechanical harvesting. To get the full economy of the pallet system one must have a satisfactory method of mechanical harvesting. The harvester we are using is a hybrid machine composed of a Noffsinger harvester, Chickering topping rolls, and Lockwood conveyor belts. Although it is not perfect, we are well satisfied with its work. Our potato and onion crops, grown on peat soil, now move smoothly and efficiently from the field directly into permanent storage with a minimum of labor. Our pallets, built of full cut oak lumber with all inside edges beveled off smoothly, are tailored to fit our particular requirements. Our main storage house consists of four rooms 50 by 100 feet each and is built on the ground level. The bottom of our clear span roof trusses are 19½ feet from the floor. To utilize the space, we made our pallets 3 ft. 10 inches in height. Stacked five high, they come within aproximately four inches of the bottom of the trusses. The pallets are 3 ft. 11 inches wide so that we can put two rows of pallets on a truck and still be within the legal width limit on the highways. Our pallets are 4 ft. 2 inches long because that is the way they come out when using four foot lumber. All pallets used hold a little more than a ton of potatoes and a little less than a ton of onions.

At the storage house all pallets are handled by motorized forklifts; one of which has a revolving head for dumping the pallets. When starting operations, we place six pallets on a six by six truck at the storage house and drive directly to the harvester in the field. The truck is driven along-side the harvester and the pallets are quickly filled. The truck returns to the storage house where the pallets are quickly removed by the fork-lifts. Six empty pallets are placed on the truck and the operation repeated. The truck drivers generally help set off the pallets and replace the empties; but one man with a high-lift fork truck does practically all the stacking in the storage house, and one man does all the pallet handling and dumping when the potatoes are being graded out of storage. We know of no other system of potato harvesting and handling as economical of man power. In addition, we know of no other system that causes as little mechanical injury to the potatoes. Once in the pallets, in the field, no further movement takes place and therefore no further injury. The dumping process can be accomplished very quickly and gently so that no injury occurs at this point. In order to dump in while grading, we use a V-shaped hopper which holds about two pallets. The hopper is well padded at the point of original impact and the drop is seldom more than two feet. These forklifts are shown in Figures 1 and 2.

The pallets, of necessity, are built with an opening four inches deep across the bottom. This opening is to accommodate the forks of the fork-lift. When the storage is filled all the potatoes are in separate packages four feet square by a little over three feet deep with air channels completely around each package. No forced movement of air is needed and the entire pile will remain close to room temperatures. If any trouble

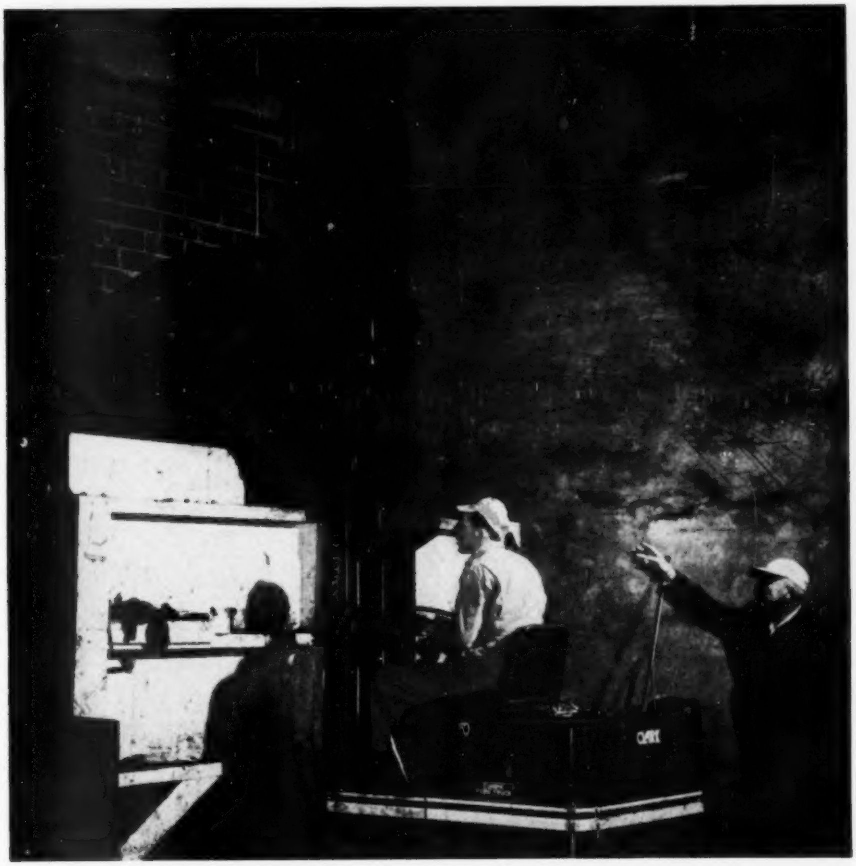

FIGURE 1.—Forklift with revolving head dumping pallet

arises from defective stock in storage, it is confined to individual pallets.

The pallet system of handling potatoes is very flexible. Any number of varieties or grades can be kept separated with no additional labor. Almost any storage space that has a good level floor can be utilized. Our mechanized system definitely causes less bruising of the potatoes than the usual method of hand picking and handling in field bags. We handle our onion harvest in exactly the same manner and with the same equipment as we do our potatoes. We dig with a two-row digger, leave the potatoes or onions in a nice compact windrow, pick them up with the harvester, deliver directly into the pallets, and haul in, and stack the pallets away in temporary or permanent storage. However, with the onions, we do force air in considerable volume directly through the product for the cooling and drying effect.

We have been using the pallet system for four years. Starting with 1,500 pallets, we now have 4,500 which is getting up close to our storage

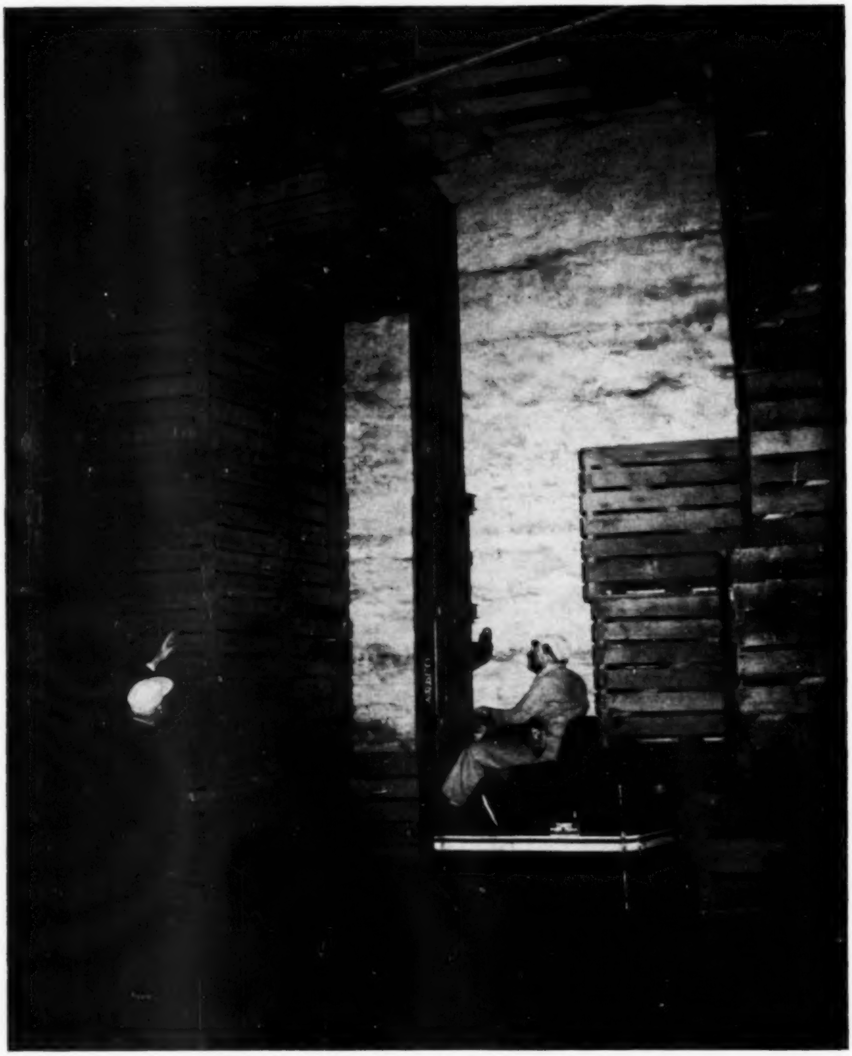

FIGURE 2.—High-lift fork truck stacking pallets in storage

capacity. Last fall, late in the season, we harvested 10,000 bushels of potatoes per day using two diggers, two harvesters, eight trucks, and a total of approximately twenty men. These potatoes were placed in permanent storage and required no further attention. We estimate it would require nearly 100 men to obtain the same results by the usual hand picking field bag method.

It is stating it mildly to say we are well pleased with our palletized system of harvesting and storing our potato and onion crops. First, of

course is the great saving in manpower; second, it is a controlled operation with a definite improvement in the quality of the product; and third, is the satisfaction of operating efficiently and keeping everything "shipshape." As I see it there is only one drawback to the pallet system, and that is the initial cost. Pallets of the size we use will cost at a very minimum ten dollars each, and might possibly cost more. Forklifts are rather expensive, and the best makes when new cost four to five thousand dollars each. An operation of any size will require at least two forklifts. Against this, we can offset the fact that these pallets, if kept under cover, will probably last longer than any one's lifetime. However, the great saving in labor will probably more than justify the original high cost.

At least two forklifts will be required for any sizeable operation.

[1]Accepted for publication, March 30, 1952.
[2]S. Kennedy and Sons, potato and onion growers and shippers, Clear Lake, Iowa.

HELP THE FLOOD-STRICKEN POTATO GROWERS OF HOLLAND

You are all familiar with the devestating flood which covered approximately 25 per cent of the acreage devoted to potatoes in Holland.

The following article explaining the conditions and needs in Holland appeared in The Packer on February 21 and we think the cause warrants all the aid we of the Potato Association of America can give. We commend the Packer and T. J. Lockwood for their sponsorship of this appeal and hope it will meet with a generous response from the Industry.—*Editor's*

KANSAS CITY, FEB. 20.—In a personal appeal for aid for flood-stricken potato growers of Holland from potato producers and dealers in the United States, Jan Berends, one of the largest potato growers of the Netherlands, spent several days with The Packer's editors in an effort to work out ways and means of carrying the appeal to the U. S. Potato Industry. The "official" go-ahead on this worthy cause was received by The Packer in the form of the following letter from the Netherlands Embassy in Washington, D. C.:

AMBASSADOR'S LETTER

WASHINGTON, D. C., FEB. 17, 1953—
Editor The Packer: With great appreciation I learned from Mr. Jan Berends that you are planning a relief action specially directed towards helping the potato growers of the Netherlands. Your action has my whole hearted support and I sincerely hope that it will prove to be a great success.

You will have realized from the accounts which Mr. Berends has been able to give you from his first hand experience that the needs in my country are very great. It is therefore that I am deeply thankful to you for initiating a relief action in Kansas City.

The result of your drive may be remitted to Holland Flood Relief, Inc., 72 Wall Street, New York, a relief organization which has been officially registered with the United States authorities and which, in its turn, will transmit all contributions directly to the Netherlands authorities.

I understand that it is your wish that the contributions you raise be earmarked for the potato growers in the Netherlands. I will see to it that everything is done to realize this wish, so that it will be this particular group in my country who will benefit directly from your generosity.

On behalf of those who will be aided by your relief action I may already express to you and to your subscribers the expression of my deep gratitude.

J. H. Van Roijen
Netherlands Ambassador

FLEW TO UNITED STATES

Mr. Berends, who visited this country some months ago to study U. S. potato industry methods as the guest of T. J. Lockwood, of the Lockwood Grader Corporation, Gering, Nebr., returned to the United States by air late last week to organize personally this appeal for his stricken country's potato industry. He is authority for the statement that about 25 per cent of the Netherlands potato acreage was flooded, representing a fourth of the 146,000,000-bushel annual production of one of Holland's basic food crops. Four hundred thousand tons of potatoes were lost in the flood. Something like 5,000 growers are affected.

It is planned, according to Mr. Berends, that the special Holland potato flood relief monies raised in this country, will go to the Dutch potato producers when they are able to return to their land, six to eight months from now, also to dealers who must re-establish their facilities. There will be many months of grueling labor for the Dutch producers before their land will be back in commercial production, variously estimated at from three to five years.

FOR SUPPLIES, MACHINERY

Their immediate needs in food, clothing and shelter are being taken care of by the Netherlands government, but the U. S. industry's monetary help will go for supplies and machinery for the long job ahead of rehabilitating the land and helping to get the industry back on its feet generally.

The Packer backs this great humanitarian appeal to potato people of the United States on behalf of their stricken brother industry-members in Holland without qualification, and with the hope that the participation will be both widespread and generous.

Checks should be sent The Packer at 201 Delaware Street, Kansas City, Mo., payable to Holland Flood Relief, Inc., with the notation that the money is to go to Netherlands Potato Growers Relief.

BULLETIN REVIEW

YIELD, TUBER SET, AND QUALITY OF POTATOES[1]

EFFECT OF IRRIGATION, DATE OF PLANTING, AND STRAW MULCH ON SEVERAL VARIETIES IN UPSTATE NEW YORK 1948-51

ARTHUR J. PRATT, JOHN LAMB, JR., JAY D. WRIGHT
AND GEORGE A. BRADLEY

This bulletin cites the results of irrigation tests with potatoes, conducted over a four-year period by the authors in cooperation with county 4-H club agents and 4-H club members in widely scattered areas in Upstate New York.

A business coupe was rigged to carry 700 feet of 3-inch aluminum pipe over the roof. The pump and fittings were carried in the trunk. Each cooperator was furnished with a standard rain gauge and rainfall records were mailed to the authors after each storm. All information was combined with the Rural Radio network weather roundup. These 2 controls made it possible to irrigate the plots whenever it was necessary.

A split-plot statistical analysis was used to determine the significance of the results, which are briefly summarized in this review.

Yields were increased significantly by irrigation every year when all locations were averaged together. The average increase from irrigation was great enough to be economically profitable under most conditions. Early planting resulted in highly significant increases over late planting during the 2 years when planting dates were compared.

The greatest variations in yield were associated with locations. The location factor was always highly significant, but the yield differences between the different locations were not constant from year to year. The authors observed that big yield differences frequently resulted from planting when the soil was slightly too wet, as compared with planting when the soil was rather dry.

Tuber set varied directly with yield in nearly all cases. Cultural factors which favored a large yield, generally favored a heavy set of tubers on each plant. This was not true of differences in set associated with varieties. Kennebec is one of the heaviest yielding varieties but sets fewer tubers than any other variety tested.

Individual tuber weight was little affected by irrigation, date of planting, or straw mulch. Here variety was the most important factor, with location second.

Specific gravity was influenced mostly by location and by variety. Even though the other factors occasionally resulted in a significant specific gravity difference, such differences were small and of little practical importance as compared with those associated with variety or location.

In general, some varieties produce relatively better in certain locations than in others. Also some varieties respond more to irrigation than others, or conversely, some varieties suffer worse from drought. The yield of those varieties that set relatively few tubers, such as Katahdin and Kennebec, is likely to be reduced less by drought than varieties such as Chenango and Snowdrift that set many tubers.

[1]Cornell Experiment Station Bulletin 876. April 1952. 36 pages.

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